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An Analysis of US Oyster Demand and the Influence of Labeling Requirements

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Abstract *In response to concerns about the morbidity rate associated with the consumption of raw Gulf of Mexico oysters, California initiated a program in March 1991 that required anyone selling raw Gulf oysters to notify potential consumers that the "consumption of raw oysters can cause serious illness and death among people with liver disease, chronic illness, or weakened immune systems." This labeling requirement, followed shortly thereafter by similar requirements in other states, received extensive media coverage. The primary objective of this study was to consider, within the context of a complete demand system, the impact of mandatory warning labels and associated media attention on the demand for the product subject to regulation and media attention (*i.e.*, Gulf product) as well as substitute products. Results indicate that warning labels lowered the demand for oysters originating from the Gulf and Chesapeake and increased demand for oysters originating from the Pacific and foreign sources. Results also indicate that the own-price flexibilities from all sources are inelastic and, with few exceptions, all products are gross substitutes for one another.*

Key words Demand analysis, oysters, warning labels, food safety event.

JEL Classification Codes Q18, Q58.

Introduction

An increasing amount of attention is being given to the role of attitudes and perceptions in shaping fisheries policy and, ultimately, the supply of and demand for seafood by both product and source. Based on a survey of relevant individuals in both the USA and Norway, Chu *et al*. (2010) provide evidence that the opinions of aquaculture stakeholders "regarding the socioeconomic and environmental benefits of aquaculture" are a key determinant of a country's aquaculture policy. The authors further hypothesize that this finding may help to explain stagnant US aquaculture production since the early 1990s vis-à-vis rapid growth in Norway's aquaculture sector. Policy that directly or indirectly stifles domestic aquaculture activities, in conjunction with relatively stagnant domestic wild

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commercial landings, implies an increasing void between the domestic supply and what is desired by consumers at an affordable price. This void is increasingly being filled by imports; generally in the form of a farm-raised product since, as is the case in the USA, harvests of many of the world's important commercial species are either stagnant or declining (Norman-López 2009). Chu *et al.* (2010) suggest that increased documentation and dissemination of factual information regarding the positive role of aquaculture—including its ability to stimulate economic development and reduce fishing pressure on wild fish stocks—may lead to increased support for aquaculture expansion in the USA and, potentially, a reduction in demand for imported, primarily aquacultured product.

While Chu *et al*. (2010) focus on the attitudes and perceptions of aquaculture stakeholders as determinants of a country's aquaculture policy and, ultimately, its aquaculture output, Roheim, Gardiner, and Asche (2007) examine, among other things, the influence of national branding as a means of differentiating seafood products and the concomitant ability by seafood buyers to price according to brand. Based on scanner data in selected United Kingdom markets, the authors found that brand can significantly influence attitudes and perceptions and, ultimately, price. As such, quality and image control can be of significant concern. Given that branding implies a reputation, the authors suggest that seafood buyers require traceability (*e.g*., history and origin of the branded product) in the supply chain and that this requirement will likely increase as branding becomes more common and the reputations at stake increase in value. The analysis presented by Roheim, Gardiner, and Asche (2007) indicates that information contained through the labeling (branding) process, under certain conditions, can be used to help achieve specified policy goals via changes in demand and relative prices.

While most seafood sold in the USA is unlikely to cause illness, almost 7% of foodborne disease outbreaks reported during 1993–97 can be attributed to the consumption of seafood (Allshouse *et al*. 2004). The safety of the seafood-consuming public is of interest to policy makers, and one method frequently used to provide increased protection is the dissemination of information on known risks associated with the consumption of products of concern. One method of conveying this information is via mandated labeling requirements. These labeling requirements can also further differentiate products and influence relative prices for the product subject to the labeling requirements and substitute products. One such example is that associated with the consumption of *Vibrio vulnificus* (*V. vulnificus*) laden raw oysters harvested from the Gulf of Mexico and mandated labeling imposed on the product in an attempt to protect at-risk consumers. *V. vulnificus* is a naturally occurring bacterium found in the Gulf of Mexico marine environment. While virtually all oysters harvested from these waters during the warmer summer months have some concentration of it (Corcoran 1998), consumption of *V. vulnificus* laden oysters is relatively innocuous for healthy individuals. Consumption can, however, lead to serious illness or death among individuals with weakened immune systems (FAO 2005). Since the Centers for Disease Control began tracking *V. vulnificus* cases in 1995, 30 to 40 cases have been reported each year, nearly all linked to the consumption of Gulf raw oysters. With an approximate 50% mortality rate, *V. vulnificus* exhibits the highest fatality-to-case ratio of any foodborne pathogen (FAO 2005).

In an effort to protect at-risk consumers, in the early 1990s a number of states began to mandate that establishments selling raw Gulf oysters notify potential consumers of the risks associated with consumption of the raw Gulf product. The state regulations that mandated labeling requirements received considerable media coverage in both the popular press and trade journals. Because consumers generally receive science knowledge from the media (Nelkin 1987) and modify their opinions and behavior based on these reports (Kone and Mullet 1994), one might expect that media coverage related to *V. vulnificus* and state labeling mandates would influence the demand for Gulf product and, possibly, substitute products. This is supported by anecdotal evidence and empirical research. With respect to anecdotal evidence, the *New York Times* and the *Daily News* ran a number of front page stories on food safety in 1998, including issues related to *V. vulnificus*. Bartholomew (1999) investigated the impacts of those media stories, with specific emphasis on the issues of food safety and perceived effects on sales in seafood restaurants in New York. When restaurateurs were asked if the Gulf oysters were safe, respondents overwhelmingly reported "no." Most restaurants, furthermore, reported having stopped buying Gulf oysters.[1] Similarly, Hardesty (2001) found that most West Coast wholesalers refused to handle Gulf oysters because of the reputed problems with *V. vulnificus*. With respect to empirical research, Keithly and Diop (2001a,b) found that, depending upon the season being considered, the Gulf of Mexico dockside price declined by 30 to 50% as a result of the *Vibrio* event.

An expected decline in the demand for the Gulf product (*i.e.*, the targeted product) is generally consistent with food safety event theory. However, there are other US oyster producing regions and, in addition to this domestic production, the USA imports a significant quantity of oysters. The impact of the Gulf-targeted warning labels and related media coverage on these substitute products is unknown, and food safety event theory provides little guidance as to the expected relationship. The primary objective of this analysis is to examine the impact of the *Vibrio* event on not just the demand for a Gulf product but also demand for substitute products.[2] Such an analysis is timely in light of recently proposed regulations that would strictly limit the sale of raw Gulf product during the warmer months.[3] An ancillary objective is that of deriving relevant direct-and-cross price flexibilities that can be used in a policy setting. This is particularly relevant in light of large ongoing and potential future government outlays to restore the Chesapeake oyster industry (National Research Council 2004), as well as increased funding being given to the Gulf Region in response to industry losses associated with a recent spate of hurricanes.

To accomplish these objectives, a brief review of the oyster industry and literature pertaining to the economics of food safety events are presented in the next section. Then, attention is turned to discussion of the model used to examine the influence of the *Vibrio* event on the demand for Gulf product as well as substitute products. The model used for analysis, based on the Inverse Almost Ideal Demand System (IAIDS) and consisting of four equations representing the major US producing regions (*i.e.*, the Gulf, the Chesapeake, and the Pacific) and imports, is then presented. The model was expanded to account for the impact of the *Vibrio* event on the demand for Gulf oysters and substitute products. After presenting the model, attention is briefly turned to reviewing the data used in the analysis. Results are then provided along with an appropriate discussion. The article concludes with a brief summary of findings.

Background

Industry Review

Nearly every coastal US state supports a commercial oyster industry, and in some states the industry is sizeable. The country's oyster production, which is highly related to environmental conditions, has averaged 38 million pounds annually since 1985 with landings ranging from about 30 to about 50 million pounds.

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[1] In a 2001 *New York Times* article, Winter (2001) stated that "[s]ince *Vibrio vulnificus* first became well known a decade ago, the price of Gulf Coast oysters has dropped nearly 30%, as demand has all but dried up in markets like Chicago and New York."

[2] In the remainder of this article, the term "*Vibrio* event" is used to refer to the combination of mandated warning labels and the associated media coverage.

[3] Specifically, in late 2009 the Food and Drug Administration announced that it intended to implement policy by the summer of 2011 that would prohibit the sale of all raw Gulf product that does not undergo post-harvest treatment to kill the *Vibrio* bacteria.

Historically, there have been three major domestic oyster producing sources: the Gulf of Mexico, the Chesapeake, and the West Coast. The primary oyster species produced from the Gulf and Chesapeake regions is the Eastern oyster (*Crassostrea virginica*), while the primary oyster species produced from the West Coast is the Pacific oyster (*Crassostrea gigas*). Being the same species, the Gulf and Chesapeake products are generally considered to exhibit the same taste and texture. However, it is generally recognized that there are significant differences in both taste and texture between the Eastern oyster (*i.e.*, that species harvested in the Gulf and Chesapeake) and the Pacific oyster.[4]

Gulf oyster production, as indicated in figure 1, exceeded 25 million pounds in 1985 but thereafter declined to a low of about 12 million pounds in the early 1990s. Following this decline, production again increased, approaching the 1985 level by the late 1990s. The decline in Gulf oyster production from the mid-1980s through 1990 is generally attributed to drought conditions that resulted in significantly reduced flow regimes of rivers emptying into the oyster-producing bays throughout the northern Gulf of Mexico and, in particular, Louisiana, which is the Gulf's largest oyster-producing state. The drought conditions hindered oyster growth and survival of the oyster populations in these bays. The drought conditions came to an abrupt end in 1991 when high rainfalls in Louisiana resulted in extensive flooding throughout coastal Louisiana and extensive oyster mortality (Caffey and Schexnayder 2002) Thereafter, salinity returned to more normal conditions as did the oyster stocks in the region.[5]

Annual Chesapeake production declined from an average of more that 13 million pounds in the mid-1980s to a low of one-half million pounds by 1993 (figure 1). While this decline is generally attributed to decimation of the Chesapeake oyster stock due to two diseases, dermo (*Perkinses marinus*) and MSX (*Haplosporidiem nelsoni)*, other explanations for decline, including a loss in reef substrate, have also been advanced (National Research Council 2004). Production from the West Coast has averaged about 10 million pounds annually since 1985, with production since 2000 generally being significantly larger than that observed prior to the most recent decade (figure 1).

Approximately 90% of the total US domestic oyster production since the 1980s has come from these three regions. Based on interviews with industry personnel, Muth *et al.* (2000) conclude that "interregional shipments of (domestic) oysters are substantial and are likely to continue to be substantial in the future."[6]

While a major oyster producer, the USA is also a significant oyster importer. These imports come in a variety of product forms including canned, smoked, and fresh/frozen. Total oyster imports have averaged 27 million pounds annually since 1985. While imports come in a variety of forms, it is the fresh and frozen imported products that most likely compete directly with domestic product. Imports of these products have averaged 7 million pounds since 1985 and have ranged from 5 million in 1994 to 14 million pounds in 2006 (figure 1). Muth *et al*. (2000) found that Canadian product, which constitutes the majority of US fresh and frozen imports, is shipped widely throughout the country and is primarily consumed in the half-shell market.

Historically, California was a major buyer of Gulf raw oysters. In response to several illnesses and deaths from consuming raw Gulf oysters, the state initiated a program in March 1991 that required anyone selling raw Gulf oysters to notify potential consumers

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[4] MacKenzie (1996) provides a detailed discussion of differences in tastes and textures among oysters grown in different areas of the USA.

[5] In addition to these 'normal' environmental events, Louisiana, in 1991, began diverting fresh water from the Mississippi River to the wetlands east of the Mississippi River (the Caernarvon Diversion Project). The operation of this diversion structure may have also contributed to reducing salinity levels over one of the state's primary oyster-producing grounds, and this may have led to increased production (see Caffey and Schexnayder 2002).

[6] In addition to the three regions discussed in this article, the Northeast can, in some periods, produce significant quantities of oysters (since 1985, the Northeast has accounted for about 5% of total US oyster production). Muth *et al*. (2000) report that interregional shipments of Northeast product is limited.

that the "consumption of raw oysters can cause serious illness and death among people with liver disease, chronic illness, or weakened immune systems." Some Gulf oyster producers harbored the impression that the "California warning labels were motivated by West Coast processors who wanted a bigger share of the Gulf-dominated oyster market" (Associated Press January 15, 1991).[7] The California mandate was followed shortly thereafter by similar actions in two of the larger Gulf oyster-producing states (Louisiana and Florida)[8] while, at the same time, the Food and Drug Administration (FDA) initiated an awareness campaign to inform the at-risk population of the potential dangers associated with consuming raw oysters harvested from the Gulf. All of these actions taken by the states and the FDA received considerable coverage in both the popular media and trade literature.

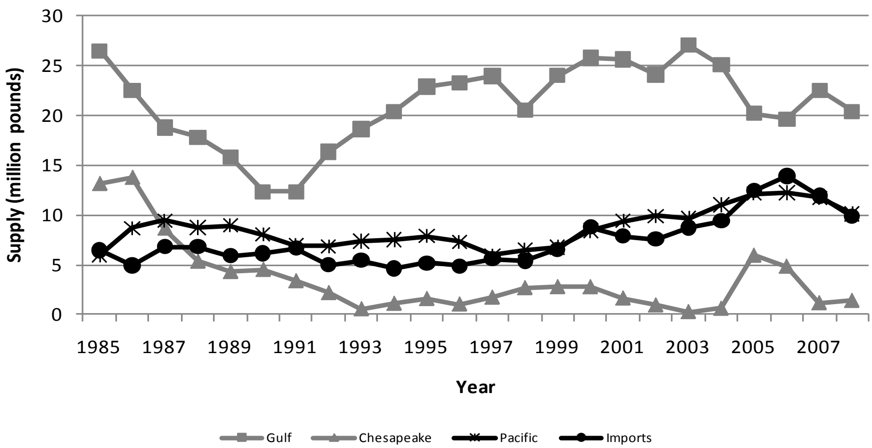

Figure 1. Annual US Regional Oyster Harvests and Imports

The deflated Gulf of Mexico dockside price fell sharply in conjunction with the media coverage, with the 1993 deflated price equaling only 40% of the 1990 price (figure 2). As the information in figure 2 further indicates, the annual deflated Gulf of Mexico dockside prices in the early 2000s remained well below those of the late 1980s. Then in 2003, because of continued illnesses and deaths, California imposed additional (April 1 through October 31) restrictions on the sale of raw oysters harvested from the Gulf of Mexico.[9] The Gulf oyster industry has contended that these additional restrictions resulted in significant economic losses to the industry.

Likewise, the Chesapeake deflated price, which closely mirrored the Gulf price during 1985–90, also declined after 1990 with its 1993 price equaling only about three-

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[7] In the initial draft of the regulation, the sale of raw oysters from any region would have triggered the warning. After meetings with state officials, West Coast oyster growers, and restaurant and retail representatives, however, the focus of the mandatory warning was narrowed to the raw Gulf of Mexico product.

[8] One important distinction between the California mandate and the mandates imposed by the Gulf states is that while the former mandate was very specific in nature (*i.e.*, warning of the health risks associated with the consumption of raw Gulf oysters), the warning labels imposed by the Gulf states were more generic in nature (warning of the dangers associated with the consumption of raw molluscan shellfish).

[9] In essence, the additional restrictions resulted in the prohibition of the sale of raw Gulf-harvested product unless the oysters were subject to a post-harvest treatment method to reduce *V. vulnificus* to non-detectable levels.

quarters of the 1990 price; despite a sharp decline in the region's landings. Despite continued lower landings in Chesapeake post-1990, the region's deflated dockside price continues, in general, to be well below the late-1980s deflated price. This continued low price may reflect *i)* increased supply of substitute products, particularly Gulf product; *ii)* the influence of media attention tied to the raw Gulf product; or *iii)* some amalgam.

Prior to the early 1990s, the Pacific ex-vessel price tended to be significantly less than that for either the Gulf or Chesapeake product (figure 2). Since the early 1990s, however, the Pacific price has generally exceeded the Gulf price and even approached or exceeded the Chesapeake price in some years during the late 1990s. With the exception of the early 1990s, the price of the imported product falls below all of the regional dockside prices.

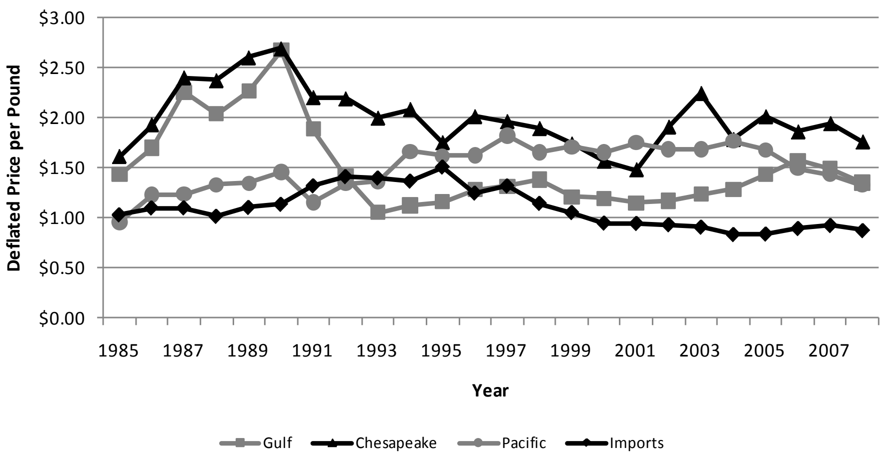

Figure 2. Annual Deflated Ex-vessel Oyster Prices by Region and Deflated Import Price (Deflated Using 1982–84 Consumer Price Index)

Selected Literature Review

One of the earliest analyses related to the economic costs associated with a food safety event was that by Shulstand and Stoevener (1978), who analyzed the welfare losses incurred by pheasant hunters in reaction to mercury contamination information. Since then, several studies have investigated the impacts of a food safety event on demand. The majority of these studies have examined the impact using a single equation approach (*e.g.*, Smith, Raavensway, and Thompson 1988; Brown and Schrader 1990; Dahlgran and Fairchild 2002). In general, empirical findings associated with these studies are consistent with theoretical expectations that negative media coverage following food contamination incidents culminates in a reduction of consumer demand for that product subject to media attention. Studies of this nature, while "capturing" the effect on the product subject to the event, fail to consider the effects on related products that are not the subject of the food safety event.

Attempts to capture the effect of a food safety event on the demand for products not directly subject to the event, or the cross-substitution effects, have focused on using a system-wide approach. One of the initial studies using this approach is that of Burton and Young (1996), who modified Deaton and Muellbauer's (1980) Almost Ideal Demand System (AIDS) to account for the impact of Bovine Spongiform encephalopathy (BSE) on the demand for beef and other meat products in Great Britain. In a similar vein, Verbeke and Ward (2001) employed a modified version of the traditional AIDS model to account for the impact of negative press on the demand for fresh meat products in Belgium. They found that TV publicity related to BSE and hormone residue scares resulted in a reduction of demand for beef and veal products (*i.e*., the products subject to the publicity) and an increase in demand for the substitute pork/mixture products.

Most recently, Mazzocchi, Monache, and Lobb (2006) analyzed the demand for meat products following multiple food scares—including two involving BSE and one involving Dioxin—in Italy over the 1996–2000 period. Using a structural time series AIDS specification which allows for changing preferences and stochastic seasonality, the researchers found that the multiple food scares lowered the beef expenditure share while, concomitantly, increased the chicken expenditure share.

Relatively few studies have evaluated the impact of food safety events on seafood demand. In 1975, the James River in Virginia was closed to all shellfish harvesting activities as a result of traces of kepone being found in several species. The contamination was widely publicized, and Swartz and Strand (1981), based on newspaper articles related to contamination of the James River, analyzed the impacts on the demand for oysters that were *i)* harvested from a spatially separated area and *ii)* used in a product that was easily differentiated from product taken from the James River.[10] The authors found that due to imperfect information, news of a contaminated product significantly impacted the demand for the alternative product (*i.e*., oysters harvested from other, isolated areas).

Employing firm-level data, Wessells, Miller, and Brooks (1995) examined the impact of information on a 1987 toxic algae (domoic acid) contamination event in Montreal, Canada, on mussel sales by a U.S firm whose product was not affected by domoic acid, as well as the demand for that firm's product. The authors found that while mussel sales of the US firm did not significantly decline as a result of the event, the demand for that firm's product did significantly decline.

Teisel, Roe, and Hicks (2002) extended the AIDS model to account for the impacts of dolphin-safe labeling of canned tuna on the demand for tuna and other related meat products. The study, while not explicitly considering the issue of food safety, is relevant because it investigates the changes in the demand for a seafood product (canned tuna) as consumers are presented with new information, through labels, about the quality of this product. Analysis indicated that a dolphin-safe label increased the market share of canned tuna product. The study also found that the presence of dolphin-safe labels has depressed the demand for luncheon meat products.

Studies examining the influence of the *Vibrio* event on oyster demand are sparse and tend to be limited in terms of the failure to examine the influence of the event on the demand for all substitute products. For example, estimating a price-dependent demand equation based on quarterly data covering the 1985–97 period, Keithly and Diop (2001a) found that the Gulf oyster dockside price fell significantly as a result of the *Vibrio* event, with the price decline being particularly pronounced in the warmer months. Using the same quarterly data, the authors subsequently extended the analysis to examine the impact of the *Vibrio* event on the Chesapeake dockside price and found that it also fell sharply as a result of the *Vibrio* event (*i.e*., warning labels and associated media coverage) tied to the Gulf product (Keithly and Diop 2001b). The authors contended that the decline in demand for the Chesapeake product may reflect a common market failure; that being an unwarranted fear held by consumers as a result of imperfect information. This finding was later supported by Lipton (2008) who, using a price-dependent demand equation, analyzed factors influencing the Chesapeake dockside price based on annual data extending from 1950 through 2006.

[10] Specifically, oysters from the James River were used primarily in either seeding activities or canning. The impact from contamination publicity related to the James River was used to examine the impact on shucked oysters distributed through the Baltimore wholesale market.

Theoretical Model and Data Considerations

The oyster demand model is estimated using an IAIDS developed by Moschina and Vissa (1992) and Eales and Unnevehr (1994). The IAIDS model possesses the same properties as the AIDS model initially proposed by Deaton and Muellbauer (1980), but is derived from the distance function rather than the cost function. The IAIDS model is generally considered to be appropriate when the quantities are considered to be predetermined and the prices are endogenous (Eales and Unnevehr 1994). Because, as noted in the *Industry Review* section, oyster availability and subsequent harvest is largely dependent upon environmental conditions, the assumption that the short-run supply of oysters is relatively fixed is likely to hold. This being the case, prices are expected to adjust to changes in production rather than vice versa.

The general linear version of the IAIDS model is given by:

$$w_{it} = \alpha_i^* + \textstyle\sum_j \gamma_{ij} \ln(q_{jt}) + \beta_i \ln(Q_{it}) + \varepsilon_{it} \; i,j = 1,...,4. \; t = 1,...,T, \tag{1}$$

where w_{it} is the budget share for the i-th oyster product at time t, q_{it} is the quantity demanded of oyster product i at time t, and Q_{it} is the Stone quantity index defined as:

$$\ln(Q_{it}) = \textstyle\sum_i w_{it} \ln(q_{it}), \tag{2}$$

which represents a modified version of the Stone price index proposed by Deaton and Muellbauer (1980) for their AIDS model.

While the use of the Stone price index is justified in the traditional AIDS model because prices tend to be highly collinear, quantities tend to be less correlated than prices and, as such, the Stone price index may not be appropriate when estimating the IAIDS (Eales and Unnevehr 1994). Thus, we used the Laspeyre quantity index expressed as follows:

$$\ln(Q_{it}) = \textstyle\sum_i \bar{w}_i \ln(q_{it}), \tag{3}$$

where $\bar{w}_i$ is the mean budget share associated with the i-th oyster source, and q_{it} is the quantity demanded of oyster product i at time t.

Based on the supply information presented earlier in this article, four products—Gulf oysters, Pacific oysters, Chesapeake oysters, and fresh and frozen imported oysters—are included in the demand analysis.[11] Seasonality in demand, changes in consumer tastes and preferences, and changes in consumers' oyster demand due to *i)* the initial mandatory warning labels and media coverage in the early 1990s and *ii)* the 2003 California ban on raw product from the Gulf during the warmer months are introduced into the general IAIDS framework as shifters of the intercepts α_i^* as follows:

$$\alpha_i^* = \alpha_0 + \textstyle\sum_{s=1}^{4} \delta_{is}\,\theta_{st} + \lambda_i t + \varphi_i * L + \omega_i * BAN. \tag{4}$$

For notational purposes, θ_{st} represents a quarterly discrete variable (θ_{st} equals 1 when season is s and 0 otherwise) used to examine the influence of seasonality on the demand for oysters, t is a time trend variable (t = 1,2,…96) used to capture systematic changes in tastes or preferences, L represents the diffusion process associated with the effects of labeling and media exposure, and BAN is a seasonal discrete variable (equal to 1 for the second and third quarters of the year from 2003 through 2008 and zero otherwise) used

[11] The Northeast product is not included based on the finding by Muth *et al*. (2000) that interregional shipments of that product are limited, while South Atlantic and Mid-Atlantic product are not included due to the minor amounts produced in these two regions since the 1980s.

to capture the impact of the seasonal prohibition on the sale of raw Gulf product in the California market. Given that the full effect associated with the early 1990s mandated labeling and media coverage likely did not occur instantaneously, but evolved over an extended period of time, the change in demand due to these events is modeled as a diffusion process. Similar to that proposed by Teisl, Roe, and Hicks (2002), we use a cumulative distribution function (CDF) of an exponential time function over the first two years (*i.e*., 1991(1) through 1992(4)) following the issue of the warning labels and a discrete (0,1) variable thereafter.[12] This diffusion functional form allows the impact from the event to gradually increase over the first two years prior to the attainment of a long-run equilibrium. Furthermore, since media coverage of illnesses and deaths associated with consumption of raw oysters is an ongoing process, with articles continuing to be routinely published, consumer concerns related to the consumption of raw Gulf oysters are constantly being reinforced. As such, it was hypothesized that the effects of the negative publicity did not gradually diminish, and the functional form used in this analysis reflects this hypothesis.[13]

To meet demand theory requirements, the following restrictions on the IAIDS demand system parameters are imposed:

$$\text{Homogeneity: } \sum_{j=1}^{4} \gamma_{ij} \tag{4a}$$

$$\text{Symmetry: } \gamma_{ij} = \gamma_{ji} \tag{4b}$$

$$\text{Adding up: } \sum_{i=1}^{4} \alpha_i = 1 \quad \sum_{i=1}^{4} \beta_i = 0 \quad \sum_{i=1}^{4} \lambda_i = 0 \quad \sum_{i=1}^{4} \gamma_{ij} = 0 \quad \sum_{i=1}^{4} \delta_{is} = 0 \quad \sum_{i=1}^{4} \varphi_i = 0 \tag{4c}$$

The system of equations in (1) can be written in matrix notation as follows:

$$w_t = \prod Z_t + \varepsilon_t \qquad t = 1,\ldots,T, \tag{5}$$

where w_t is 4×1 vector of expenditure shares at time t, Π is 4×K matrix of unknown parameters in the system at time t, Z_t is K×1 vector of explanatory variables at time t, and ε_t is 4×1 vector of error terms at time t that are assumed to follow multivariate normal distribution with mean zero and covariance Σ.

The system comprised of four share equations in (1) with the theoretical restrictions (homogeneity and symmetry) imposed was estimated using the iterative non-linear seemingly unrelated regression estimation procedure (ITSUR) in SAS (2002). Since the expenditure shares add up to one, the error covariance matrix of the residuals is singular, implying the need to delete one of the equations prior to estimation. The result of the system is invariant to the choice of equation to be dropped, and parameter estimates associated with the deleted equation may be retrieved using the adding up conditions.

Data and Estimation Method

Data used in this analysis are quarterly time series data covering the period 1985(1)–2008(4). The prices and quantities associated with the four products included in the

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[12] More specifically, the diffusion function takes a zero value prior to the first quarter of 1991 and follows an exponential CDF curve for the next two years at which point it takes a value of 1.

[13] We also tested if the impact of the *Vibrio* event follows a quadratic functional form. This alternative specification allows the impact to initially increase after the initial labeling requirements, and thereafter the effect is allowed to "wear off." The result of the quadratic specification did not show any evidence that the impact associated with the *Vibrio* event diminished over the sample period.

analysis are derived from data maintained by the National Marine Fishery Service (NMFS). All quantities (*i.e.*, landings by region and imports) are converted to a per capita basis for purposes of analysis.[14]

The Gulf product, as indicated by the information in table 1, represented more than one-half of the total expenditure shares for the four oyster products over the sample period, while the Pacific product, on average, represented an additional 20% (table 1). Imports represented 14% of the expenditure share during the 1985–2008 period, while the Chesapeake product, which exhibited the most variability in expenditure share as measured by the standard deviation, represented the remaining 10%. The high variability in the Chesapeake expenditure share is expected given the sharp decline in the region's production during the period of analysis (see figure 1).

Table 1
Summary Statistics Associated with Variables used in Analysis

	Mean	Std.	Min.	Max.
Expenditure shares				
Gulf	0.539	0.078	0.306	0.671
Chesapeake	0.101	0.117	3.00E-04	0.511
Pacific	0.213	0.059	0.071	0.336
Imports	0.147	0.073	0.032	0.391
Supply (lbs./1,000 persons)				
Gulf	19.438	5.673	8.898	41.473
Chesapeake	3.531	5.361	0.004	30.903
Pacific	7.948	2.525	4.125	15.280
Imports	6.685	2.752	2.513	14.710

The high variability seasonal (*i.e.*, quarterly) supplies in each region (and imports) are also evident from the information presented in table 1. In the Gulf Region, for example, per capita supply ranged from less than 9 pounds per thousand persons to over 40 pounds. Variability in the Chesapeake supply is even more apparent with a range from only 0.004 per thousand persons to over 30. As one would expect, the quantity information tends to somewhat mirror the expenditure share information with differences between the two reflecting differences and changes in absolute prices.

Empirical Results and Discussion

The parameter estimates of the four IAIDS models are presented in table 2.[15] As indicated, most of estimated parameters are significant and exhibit the theoretically expected signs. The proposed model seems to fit the data well based on the values of the adjusted

[14] Some of the NMFS quantity and value information associated with Chesapeake production in later years was not in agreement with state data. The state data were thought to be more reliable (the NMFS data showed unrealistically high prices in some periods) and hence were used in the analysis.

[15] While most literature indicates that short-run variations in oyster populations and harvests are environmentally induced, a Wu-Hausman test was conducted to determine whether quantities could be considered as predetermined; a prerequisite for using the IAIDS. Results associated with this test are presented in Appendix table A.1.

R-squares (table 2). Furthermore, the values of the Durbin-Watson test, as reported in table 2, did not exhibit evidence of serial correlation in the model.[16]

Table 2
Estimated Parameters from the IAIDS Model for Oysters[a]

Variable	Gulf	Pacific	Chesapeake	Imports
Intercept	0.313***	0.155***	0.322***	0.210***
	(0.022)	(0.013)	(0.020)	(0.016)
Gulf	0.174***	–0.082***	–0.025***	–0.067***
	(0.013)	(0.009)	(0.006)	(0.009)
Chesapeake	–0.025***	–0.014***	0.040***	0.000
	(0.006)	(0.004)	(0.007)	(0.003)
Pacific	–0.082***	0.139***	–0.014***	–0.043***
	(0.009)	(0.011)	(0.004)	(0.008)
Imports	–0.067***	–0.043***	0.000	0.110***
	(0.009)	(0.008)	(0.004)	(0.009)
Quantity index	–0.006	0.071***	–0.033	–0.033*
	(0.034)	(0.022)	(0.040)	(0.019)
Season1	0.023*	0.022**	–0.050***	0.004
	(0.014)	(0.009)	(0.017)	(0.008)
Season2	0.044**	0.052***	–0.119***	0.022*
	(0.020)	(0.015)	(0.023)	(0.013)
Season3	0.046**	0.057***	–0.112***	0.010
	(0.023)	(0.016)	(0.027)	(0.015)
Vibrio event	–0.143***	0.092***	–0.050*	0.101***
	(0.025)	(0.015)	(0.029)	(0.014)
BAN	–0.064***	–0.030**	0.084***	0.010
	(0.020)	(0.012)	(0.025)	(0.010)
Trend	0.002***	0.000	–0.001	–0.001***
	(0.000)	(0.000)	(0.000)	(0.000)
Adj. R^2	0.67	0.80	0.76	0.90
Durbin-Watson	1.74	1.98	1.80	1.52

[a] Standard errors are reported in parentheses.
*Significant at 10%; **Significant at 5%; ***Significant at 1%.

For the Gulf share equation, as indicated by the information in table 2, the parameter estimate associated with the *Vibrio* event variable (φ) is negative and statistically significant. Given the label diffusion function used in this model, the full impact of the *Vibrio* event was not experienced until the fourth quarter of 1992.[17] This finding is consistent

[16] A test for serial correlation in the system was also conducted with results presented in Appendix table A.2.
[17] We estimated the IAIDS model using several different ending time periods for the label diffusion function, and lack of fit (as measured by the value of the log-likelihood function) associated with each analysis was compared with the log-likelihood value of the model with no labeling effect. The results of this test indicated that the model with the label diffusion function ending at the fourth quarter of 1992 had the smallest log-likelihood value. Therefore, that time period for the label diffusion function was adopted.

with other studies evaluating the impact of safety events for the food product which is the subject of the event (*e.g.*, Mazzocchi, Monache, and Lobb 2006) and supports the hypothesis that warning labels and associated media attention significantly reduced the demand for Gulf product, *ceteris paribus*. Similarly, the *Vibrio* event coefficient (φ) is negative and marginally significant in the Chesapeake share equation. This finding, which is consistent with that reported by Keithly and Diop (2001b), indicates that the *Vibrio* event associated with the Gulf product resulted in a reduction of demand for the Chesapeake product and may suggest imperfect information (in terms of media exposure) being received by the consuming public and/or the inability of the consuming public to identify product source. This finding is anticipated since, as noted, the same oyster species (*i.e.*, the Eastern oyster) is produced in both the Chesapeake and the Gulf.

Unlike Gulf and Chesapeake products, however, the *Vibrio* event associated with the Gulf product was found to increase the demand for both Pacific and imported products, as indicated by the positive and significant signs of the parameter (φ) in both equations. These results suggest that warning labels on the Gulf product and related media coverage resulted in substitution of the Gulf product (and Chesapeake product) to Pacific and imported products. This is consistent with what was reported by both Bartholomew (1999) and Hardesty (2001).

To measure the long-run impact associated with the *Vibrio* event, we predict the expenditure share for each source with and without the event (*i.e.*, setting the relevant coefficients in table 2 equal to zero). After doing so, the two values are compared, and the total impact associated with the event for each source is calculated as the percentage change in the predicted expenditure share of that source over the period 1991(1)–2008(4). Based on this procedure, the *Vibrio* event was found to reduce the market share of the Gulf product by almost 20%. More specifically, the hypothetical expenditure share of the Gulf product over the sample period in the absence of the *Vibrio* event was found to average 67% of total market share compared to only 54% when the impact of the *Vibrio* event is considered **(**figure 3**)**. Similarly, the market share for the Chesapeake product fell from an estimated 11% of the total in the absence of the *Vibrio* event to only 7% after accounting for it. By comparison, the predicted market share for the Pacific product was estimated to average about 15% in the absence of the *Vibrio* event compared to 24% when it is taken into account. This implies a nearly 60% increase in the market share of the Pacific product associated with *Vibrio* event. Finally, the results indicate that the *Vibrio* event culminated in a near doubling of the market share of the imported product.

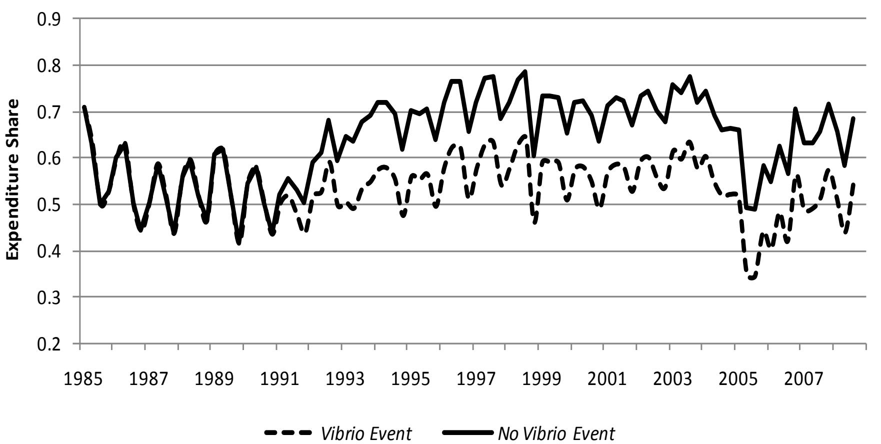

Figure 3. Estimated Impact of the *Vibrio* Event on the Gulf Market Share

The analysis also indicates that that, as expected, the 2003 California regulation restricting the sale of raw Gulf product in the warmer months (*BAN*) resulted in a decline in demand for the Gulf product during the warmer months (April through September), with its estimated market share falling by approximately 6%. Somewhat unexpectedly, however, the 2003 California regulation was found to have also resulted in a reduction in the demand for Pacific product.[18] Finally, the California regulation was found to significantly influence the demand for Chesapeake product, while not significantly influencing the demand for imported product.

The coefficient of the time trend variable with respect to the import share equation (λ) was negative and highly significant, indicating a downward trend in the demand for the imported product, *ceteris paribus*. On the other hand, the respective time trend coefficients (λ) associated with the Gulf share equation was positive and statistically significant. This finding was somewhat unexpected in light of the impacts that the *Vibrio* event and the California ban were found to have had on the demand for Gulf oysters. While statistically significant, the overall long-term impact associated with the trend variable on demand for the Gulf product is minor.

The uncompensated price and scale flexibilities (calculated at the sample means) along with the appropriate standard errors are reported in table 3. All own-price flexibilities were found to be negative and less than one in absolute value, implying that oysters from all four sources are price inflexible. Gulf and Chesapeake oysters exhibited the largest own-price effects among the four sources. A 10% increase (decrease) in Gulf supply was found to result in a 6.8% decrease (increase) in its normalized dockside price, while the same percentage increase (decrease) in Chesapeake supply was associated with an approximate 6.4% decrease (increase) in its normalized ex-vessel price. By comparison, a 10% increase in either the Pacific supply or import supply was found to culminate in less than a 3% reduction in their respective normalized prices.

Table 3

Uncompensated Price Flexibilities[a]

	Gulf	Chesapeake	Pacific	Imports	Scale
Gulf	–0.683***	–0.048***	–0.155***	–0.126***	–1.011***
	(0.038)	(0.009)	(0.025)	(0.020)	(0.062)
Chesapeake	–0.424*	–0.639***	–0.209**	–0.052	–1.322***
	(0.239)	(0.064)	(0.105)	(0.073)	(0.400)
Pacific	–0.205***	–0.033**	–0.273***	–0.154***	–0.664***
	(0.056)	(0.014)	(0.066)	(0.039)	(0.103)
Imports	–0.574***	–0.025	–0.340***	–0.283***	–1.223***
	(0.077)	(0.019)	(0.066)	(0.071)	(0.129)

[a] Standard errors are reported in parentheses.
* Significant at 10%; ** Significant at 5%; *** Significant at 1%.

All cross-price flexibilities, with the exception of two pairs (Chesapeake-import and import-Chesapeake) were found to be negative and statistically significant, implying that the majority of oyster products, differentiated by source, are gross substitutes.

[18] The finding of a reduction in demand for the Pacific product may reflect an unusually high reported number of *V. parahaemolyticus* outbreaks in recent years associated with consumption of raw Pacific oysters in the warmer months. It is hypothesized that the increasing number of outbreaks is related to rising ocean temperatures in the region.

The results indicate that changes in the quantity of Gulf product, in general, have a strong cross-substitution effect on oyster prices from other sources. Specifically, a 10% increase in the supply of Gulf product was found to result in a 4.2% decline in the Chesapeake dockside price and a 5.7 and 2.1% decline in the respective import and Pacific dockside prices. While a change in Chesapeake production was found to statistically influence both Gulf and import prices, even large changes in current Chesapeake production, say by a factor of 10, would have only modest impacts on the prices of these substitute products due to small current production in the region.

All scale flexibilities (*i.e.*, the percentage change in the normalized price of each oyster product for a proportional change in production of all four types of oyster products) were found to be negative, as suggested by theory, and statistically significant (table 3). A 10% increase in supply of all four oyster products was found to result in a 6.6% decrease in the normalized price of the Pacific product compared to an 11–12% decrease in prices from other supply sources.

Concluding Remarks

Oysters are grown in virtually all coastal states, and in some states the oyster industries are sizeable, generating significant employment and income. Unlike most seafood products, however, a significant proportion of oyster consumption involves raw product. Consumption of raw oysters originating from the Gulf of Mexico can result in illness and even death among individuals with weakened immune systems. California and other states have taken various actions—primarily the requirement of warning labels—in an effort to protect at-risk individuals. These actions have resulted in considerable attention in print media and trade journals.

Using an IAIDS framework, this article examines the influence of mandatory warning labels and associated media coverage (*Vibrio* event) tied to the raw Gulf product on the demand for Gulf product and also on the demand for products that are considered to be possible substitutes for the Gulf product. These substitutes include Chesapeake oysters, Pacific oysters, and imported oysters. Overall, the analysis indicated that the demand for the Gulf and Chesapeake products fell sharply as a result of the event, while the demand for the Pacific and imported products sharply increased. The finding that regulations and media coverage attached to the Gulf product negatively influence the Chesapeake price, while consistent with the findings reported by Keithly and Diop (2001b) and Lipton (2008), suggest a possible market failure in the form of imperfect information being transmitted through the market system. This, in turn, suggests a possible role for government intervention premised on the benefits from government intervention (gains in surplus associated with more accurate information) exceeding the costs.

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Appendix

Endogeneity Test

One of the assumptions of the IAIDS model is that is that quantities are predetermined. For the current study, this assumption is tested using the Wu-Hausman test. This test compares the parameter estimates using two different estimators: the first estimator (restricted SUR) is efficient and consistent under the null hypothesis that the quantities are predetermined; however, it is inconsistent under the alternative hypothesis that the oyster quantities are endogenous. The second estimator (restricted 3SLS) is consistent under both the null and the alternative (see Wu (1973), Hausman (1978), and Thurman (1986)). A rejection of the null hypothesis is an indication that one or more quantities may be endogenous, in which case the use of the IAIDS model becomes questionable. To employ this test, we used first lags of each of the four oyster products as instruments. The result of the Wu-Hausman endogeneity test, as reported in Appendix table A.1, confirms that all oyster quantities can be taken as predetermined, which provides additional support for the use of the IAIDS model.

Table A.1
Results of the Wu-Hausman Endogeneity Tests of Oyster Quantities

Null Hypothesis	Test Statistic	Degrees of Freedom	*p*-value
Predetermined quantities	16.73	36	0.997

Test for Serial Correlation

A test for the presence of first-order serial correlation in the system was made following the procedures outlined by Berndt and Savin (1975), Edgerton and Shukur (1999), and Kim (1994). Assume that the error terms in equation (5) follow a first-order serial correlation pattern. As such, they can be written as:

$$\varepsilon_t = R\varepsilon_{t-1} + v_t \quad t = 2,\ldots,T, \tag{6}$$

where R is 4×4 matrix of unknown parameters and v_t are independently identically distributed normal random errors with mean zero and covariance matrix Σ (Berndt and Savin 1975).

A test for first-order serial correlation in the system is equivalent to testing whether the elements of the matrix, R, are jointly equal to zero. Rejecting the null implies that the errors are serially correlated, in which case correction for serial correlation would be required to obtain efficient estimates. On the other hand, if the null hypothesis is not rejected, one can conclude that there is no evidence of serial correlation. The likelihood ratio test was used to test for the presence of serial correlation in the system. The result of this test is reported in Appendix table A.2 . The value of the likelihood ratio test is 19.51 and the p-value of this test is 0.08, so we do not reject the null hypothesis that the errors are serially uncorrelated at the 5% level of significance.

Table A.2

Log-Likelihood Ratio Test for the Presence of Serial Correlation in the IAIDS Model

Null Hypothesis	Test Statistic	Degrees of Freedom	p-value
No autocorrelation	19.51	12	0.08